Appendix C: Capacity of the California Squid Fishery

Evaluating the capacity of the current market squid fishery can be used to provide a basis for establishing a restricted access program that matches the level of effort in a fishery to the health of the fishery resource. The goal of such a program should be to maintain a sustainable squid resource and should provide for a fishery that is diverse, stable and profitable. With the establishment of the moratorium in 1998, many vessels applied for permits that were never active in the fishery. These purchases led to a situation where excessive and currently unutilized capacity is present among permitted vessels of the fleet. During peak landing periods, the number of active vessels was still significantly below the number of currently permitted vessels. No data exist that indicates that the squid resource is capable of sustaining harvests above the current level. Further, present market conditions do not indicate there is room for substantial increases in the number of vessels participating.

Methodology for Determining Current Capacity

A data envelopment analysis (DEA) was conducted using landings data and information on vessel characteristics to estimate squid harvesting capacity of both the active and inactive squid fleet. DEA is a means to estimate the physical harvesting capacity for each vessel given its capital stock (represented by its gross tonnage) and observed output (represented by volume of the single best catch of squid on record). DEA determines which vessels, in terms of their gross tonnage, delineate a best-practice frontier.

The best-practice frontier defines the maximum catch of squid per trip that can be produced by a vessel of a distinct gross tonnage. From the best-practice frontier, the harvesting capacity of any vessel in the fleet, active or not, may be estimated by deriving an anticipated maximum catch from this relationship with gross tonnage, even without specific knowledge of the vessel's hold volume. In this sense, physical capacity provides a benchmark maximum harvesting potential for a given vessel or fleet of vessels.

The second variable in determining harvesting capacity is to approximate the frequency of trips a vessel can be expected to fish for squid under what are considered typical or normal operating conditions. This capacity concept incorporates the fisherman's expectations concerning variations in resource availability, environmental conditions and market demand. Further, it is considered a technological-economic measure of capacity.

Maximum physical capacity is appropriately associated with some peak availability of squid, unique environmental conditions that enhance production, or peak demand for output. Technological-economic capacity accounts for typical patterns of resource availability, environmental conditions and market demand. These factors are highly variable are highly variable for the squid fishery. Likewise, technological-economic capacity of individual vessels (and the fleet overall) is highly variable between and within fishing seasons.

To estimate an individual vessel's harvesting capacity for a given season, the maximum foreseeable catch of the vessel is multiplied by a number of trips per year, values that are determined by applying a varying range of assumptions. Therefore, several estimates of fleet capacity can be determined under various modes of operation for a given season, and the most appropriate estimate can be selected.

Physical Capacity

Based on recommendation by the Squid Fishery Advisory Committee (SFAC) for considerations of transferability in extenuating circumstances during the moratorium period, the Department has implemented the use of the standard formula for determining gross tonnage, a measure of vessel capacity. As described in 46CFR69.209, gross tonnage is defined by (0.67 x vessel length x vessel breadth x vessel depth) ÷ 100. At the time of this analysis (January 2001), the gross tonnage of 192 permitted vessels were identified in the vessel permit database, although the revised figure as of February 2001 is 197. No information was available for nine of the vessels.

Although these capacity estimates do not account for variations in hold size between vessels of similar gross tonnage, complete utilization of available fish hold space (if the information were available) cannot be assured due to frequent limitations imposed by stability or wastewater concerns.

Active vs. Inactive Vessels

Of the 192 permitted squid vessels in the 2000-2001 fishing season, 140 made at least one landing of squid between 1981 and 2000, the period for which computerized landing receipt data is available. As with many moratorium fisheries, it is likely that many permits were purchased on speculation that they would eventually have a high resale value, or that holding a permit may secure a future fishing opportunity. Since the composition of active vs. inactive vessels is not homogeneous, capacity of inactive vessels is considered separately. Examination of capacity information for active vs. inactive vessels indicates a significantly greater portion of the inactive vessels have smaller gross tonnages (Table C1, Fig. C1), as the mean values differ substantially. Many of the permitted vessels without documented participation are light vessels currently active in the fishery that purchased a vessel permit in order to preserve the right to land squid in excess of 2

tons per trip should there be an increase in demand or opportunity for a premium squid market using brail gear.

Table C1. Gross tonnage comparison between inactive (left columns) and active (right columns) vessels in the market squid fishery

	Number of Vessels	
Gross tonnage	Active Vessels	Inactive Vessels
10	0	5
20	19	32
30	9	19
40	14	16
50	16	19
60	12	15
70	22	23
80	12	15
90	7	7
100	6	7
110	1	2
120	7	7
130	3	4
140	3	5
150	2	2
160	3	4
170	0	0
180	0	0
190	0	0
200	0	0
210	1	1
no data	3	9
Average gross tonnage:	67	62

Performance of Active Vessels

For vessels where both catch and capacity information were available (N=137) evaluation of the relationship between catch and capacity demonstrates that increased capacity yields an increased maximum catch (fig. C1), indicating that physical capacity of an individual vessel is meaningful measure by which to evaluate fleet capacity. For the purposes of this analysis, the maximum landing of squid recorded during the 1981-2000 time period may be a reasonable measure of maximum trip capacity on a per-vessel basis, although alternative approaches may be considered (i.e., maximum landing made by a vessel of any species on record). To address potential errors in the commercial landings database, extreme outliers were identified based on examination of other landings made by the vessel and were eliminated if necessary, applying a “common sense” filter.

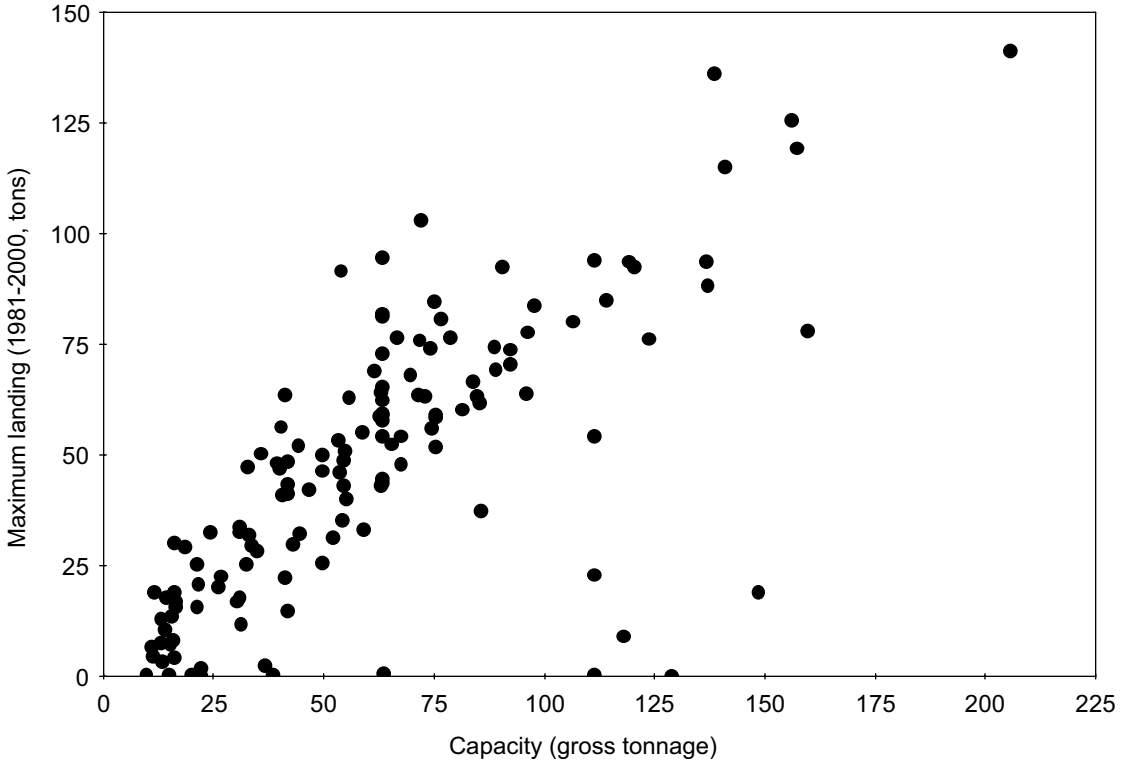

Figure C1. Relationship between gross tonnage and maximum squid landings per vessel permitted in 2000-2001.

From this relationship it was possible to determine what the maximum expected output, in terms of catch per trip, might be for each vessel of known capacity. Fitting a curve to the vessels that have the highest output given their capacity allows us to calculate a relative measure of efficiency for each vessel which falls below the fitted line (fig. C2). Vessels that are on the regression line are considered to be fully efficient (based on the three data points used to derive the curve), and are deemed

to be on the "frontier" in terms of output.

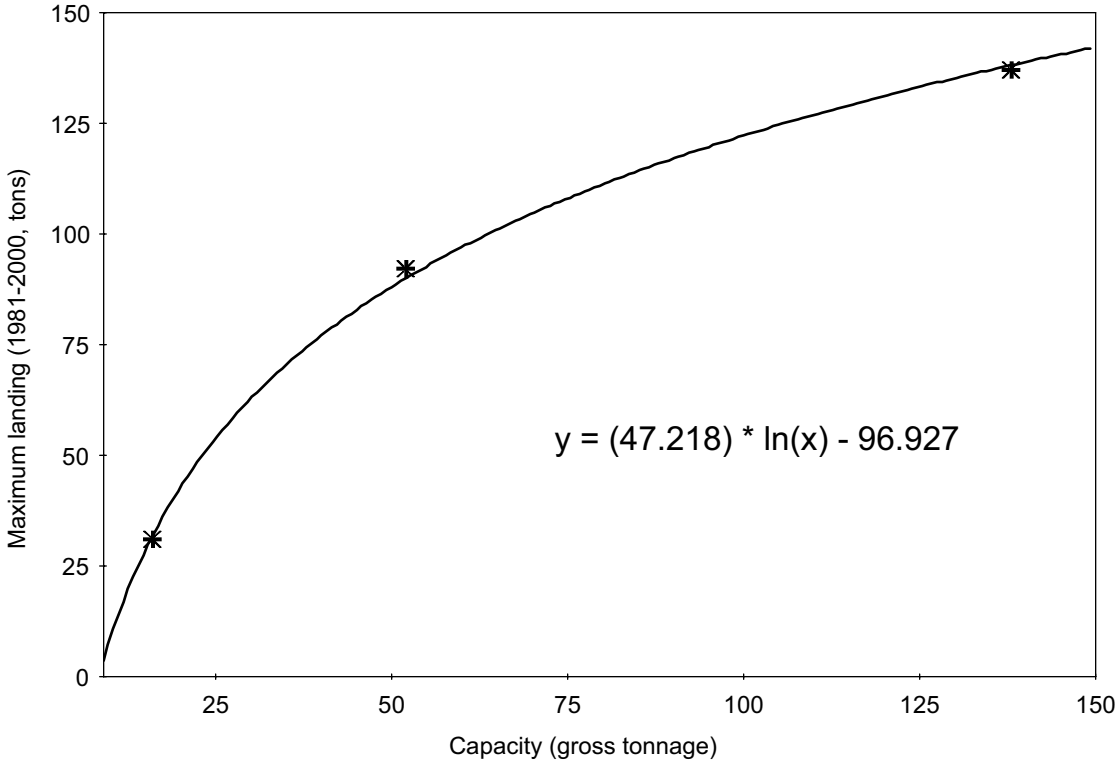

Figure C2. Theoretical maximum landing per trip of market squid based on vessel capacity.

Inefficiency was calculated for each vessel not on the frontier curve by taking the ratio of the theoretical maximum attainable catch to the actual recorded maximum landing. The median inefficiency value of 1.84 (Table C2) can be interpreted to mean that if the median vessel operated at 1.84 times its current efficiency, it would also fall on the frontier curve for fully efficient vessels.

Table C2. Distribution of vessel inefficiency values for active squid permitholders.

Inefficiency value	Frequency
1.0	10
1.2	13
1.4	21
1.6	18
1.8	21
2.0	7
2.2	8
2.4	4
2.6	5
2.8	3
3.0	2
3.2	1
3.4	2
3.6	1
3.8	2
4.0	2
5.0	6

Table C2. Distribution of vessel inefficiency values for active squid permitholders.	
Inefficiency value	Frequency
≥ 10	10
Median	1.8

Given this information, it is possible to determine an approximation for the theoretical maximum volume of catch for all permitted vessels that have ever made a landing (n=140). If all vessels were to land all of their theoretical maximum landing in a single trip, considered to reflect a day of operation, this would amount to 12,300 tons being landed daily (Table C3). Additionally, if these calculations were expanded to include all 192 permit holders, theoretical maximum daily landings would amount of 15,542, which includes a daily latent capacity of 3,243 tons (note: a median capacity value was applied for the nine vessels where no capacity information was available). During the period of 1981-2000, summing the highest observed daily maximum landing over the 20-year period for all active vessels yields 6,572 tons daily rather than 12,300 tons, if all vessels performed at the "frontier" level for a single day. This indicates that even at their best performance, vessels in the fleet do not optimize their capacity.

Table C3. Theoretical daily maximum production by active and inactive vessels.		
	Theoretical daily maximum (tons)	Maximum daily catch, 1981-2000
Daily maximum capacity for vessels making at least one landing (n=140)	12,299	6,572 ST
Daily maximum capacity for all permitholders (n=192)	15,542	N/A
Difference (daily latent capacity)	3,243	N/A

Consequently, use of information on theoretical daily maximum volume is not a realistic measure of fleet capacity, although it serves as a useful benchmark in terms of what the existing fleet could be capable of under perfect operating and market conditions. At a minimum, this information serves to document that there is more than adequate physical capacity in the fleet to catch the highest catch on record several times over.

Fleet Effort Considerations

To determine a more realistic fleet capacity estimate incorporating variations in fishing effort, information is needed on how many trips a vessel is anticipated to take per year or season where it may provide any output (i.e., catch) per trip. Simply arriving at a physical measure of capacity does not take into consideration the reality that fisheries are impacted by social, economic and environmental factors which affect a vessel's ability to participate during a season which must be considered quantitatively in determining overall fleet capacity.

Specifically, the squid fleet is diverse in that many vessels also participate in other fisheries such as sardine, mackerel, herring or salmon which may impact the number of days fished for squid in a season. Additionally, fishery activity reflects extreme variability due to squid availability during El Niño and La Niña periods, causing volume as well as seasonality of the fishery to fluctuate radically. Averaging several seasons may also pose problems as significant expansion of the southern California squid fishery occurred between 1981-2000 and some vessels did not participate in some seasons due to El Niño or market conditions.

It may be reasonable to look at the maximum number of landings a single vessel has made in a given season as an approximate measure of what the fleet would be capable of producing under optimal conditions. However, after scrutiny of the squid landings database, using the number of landings in a season may be an erroneous measure of maximum potential effort, as more than one landing per day by the same vessel and same dealer frequently appears in the database. Some dealers may split a boat's catch onto more than one landing receipt depending on the trucking and offloading process. Consequently, the number of landings, the number of seasons of participation, and the number of days with landings were evaluated independently, and the number of days fished was selected as the preferred method to evaluate fishery activity levels (Table C4).

Table C4. Seasons of participation from 1981-2000 by vessels permitted for the 2000-2001 squid fishery.

Seasons of Participation, 1981-2000	Number of Vessels	Cumulative Total
20 seasons	2	2
19 seasons	5	7
18 seasons	2	9
17 seasons	2	11
16 seasons	4	15
15 seasons	6	21
14 seasons	5	26
13 seasons	3	29
12 seasons	4	33
11 seasons	5	38
10 seasons	4	42
9 seasons	7	49
8 seasons	6	55
7 seasons	6	61
6 seasons	8	69
5 seasons	12	81
4 seasons	7	88
3 seasons	17	105
2 seasons	22	127
1 season	13	140
0 seasons	52	192

Table C5. Historical number of landings (1981-2000) for vessels permitted in the 2000-2001 squid fishing season.

Number of landings	Number of vessels	Cumulative Total
>=1000	8	8
900-999	3	11
800-899	5	16
700-799	4	20
600-699	4	24
500-599	10	34
400-499	7	41
300-399	16	57
200-299	18	75
100-199	4	79
90-99	2	81
80-89	3	84
70-79	8	92
60-69	1	93
50-59	5	98
40-49	5	103
30-39	11	114
20-29	11	125
10-19	10	135
1-9	5	140
0	52	192

Table C6. Historical number of days with landings (1981-2000) for vessels permitted in the 2000-2001 squid fishing season.

Number of days with landings (1981-2000)	Number of vessels	Cumulative Total
>=1000	1	1
900-999	3	4
800-899	3	7
700-799	9	16
600-699	5	21
500-599	9	30
400-499	8	38
300-399	6	44
250-299	11	55
200-249	7	62
150-199	10	72
100-149	21	93
50-99	15	108
25-49	16	124
10-24	16	140
0-10	42	192

Because vessels of varying capacity may have been able to participate at different levels based on their physical constraints, it is important to consider the reality that vessel capacity could impact a vessel's ability to make landings. There does not appear to be a relationship between capacity and the number of landings made (fig. C3), number of seasons of participation (fig. C4), or the number of days in a season a vessel has participated (fig. C5). Consequently, no attempt was made to apply different effort values to various vessel capacity levels.

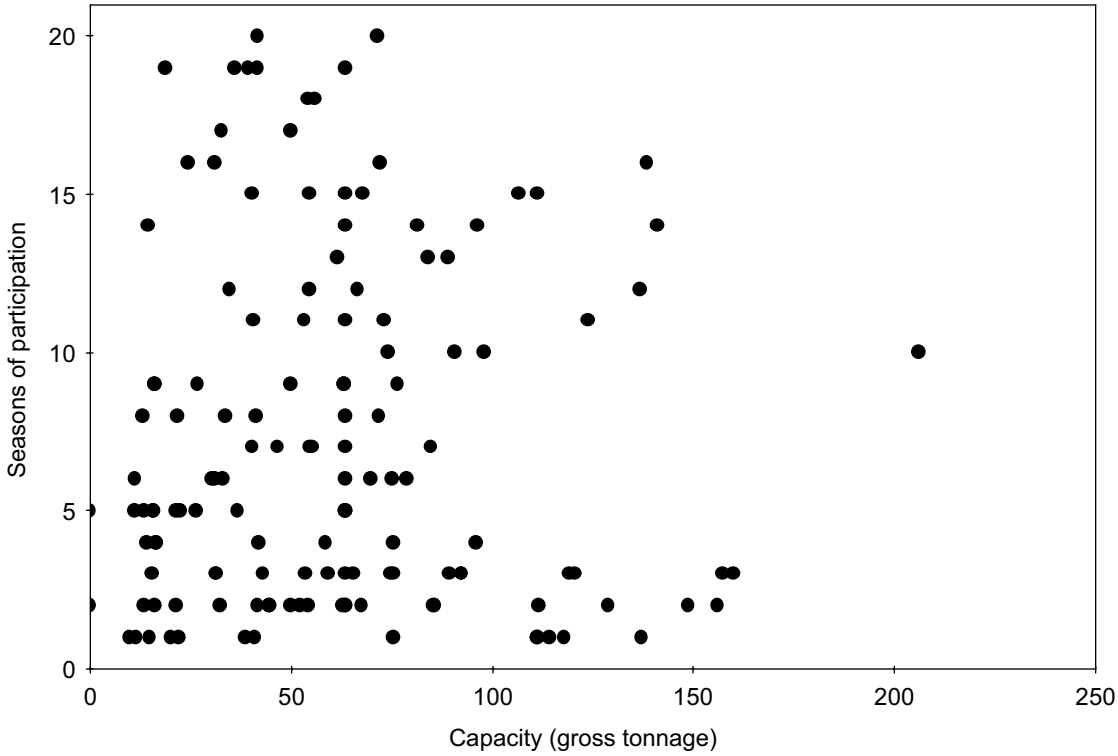

Figure C3. Relationship between number of seasons of fished for squid and gross tonnage from 1981 through 2000 (relationship not significant; r = 0.01).

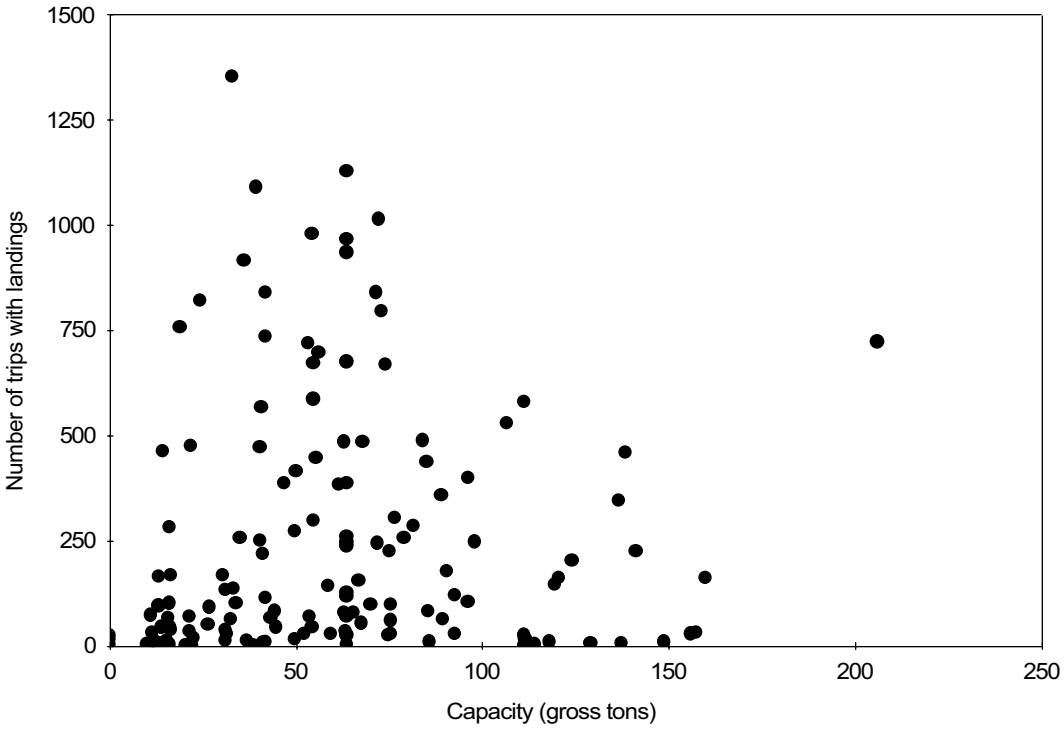

Figure C4. Relationship between number of squid trips and gross tonnage (trips measured by landings) from 1981 through 2000. Note: no significant relationship exists (r=0.05).

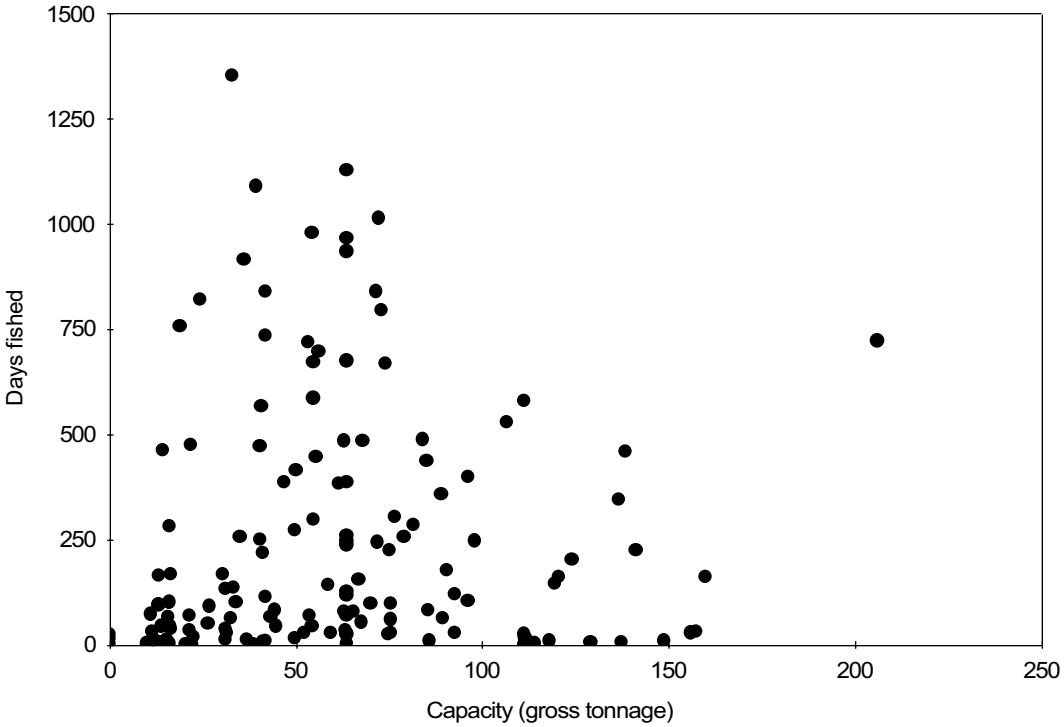

Figure C5. Relationship between the number of days fished for squid and gross tonnage from 1981 through 2000 (note: relationship not significant; r = 0.05)

Approximating trips per season

Presuming there is no relationship between capacity and a vessel's ability to make landings, the maximum recorded number of days in a season (130 days, the highest value in Table C7, column J) per vessel was selected as one option to evaluate maximum output per vessel by which overall fleet capacity may be estimated. However, the maximum average number of days squid were landed by a single permit holder in a season (45 days, the highest value in Table C7, column K) may serve as the best estimate of the maximum effort expected to be exerted by the fleet overall. The impact of applying each of these effort values is reflected in the capacity options summarized in Table C8.

Table C7. Summary of maximum and average seasonal vessel participation, 1981-2000.

Season	A	B	C	D	E	F	G	H	I	J	K
1980	5768.2	1619.9	0.281	55	11	433	97	17	8.8	17	8.5
1981	25851.3	11573.3	0.448	152	31	3581	1620	130	52.3	99	44.5
1982	13213.1	7204.1	0.545	125	26	2722	1276	118	49.1	86	37.9
1983	1087.1	741.3	0.682	81	17	423	170	36	10.0	28	8.8
1984	1353.5	478.6	0.354	95	22	469	176	27	8.0	20	6.5
1985	14375.5	9471.7	0.659	126	37	1793	985	118	26.6	65	21.1
1986	25602.5	20245.5	0.791	122	39	2409	1662	162	42.6	91	33.5
1987	25213.5	20892.3	0.829	117	38	1937	1428	116	37.6	86	30.8
1988	48195.2	36418.5	0.756	119	46	2594	1795	134	39.0	121	34.8
1989	33051.3	24702.3	0.747	100	42	2037	1417	141	33.7	89	29.7
1990	32472.2	27659.8	0.852	102	43	1829	1476	104	34.3	86	29.5
1991	38666.0	34395.5	0.890	85	44	1735	1502	103	34.1	96	30.4
1992	18793.4	16865.7	0.897	82	41	1394	1143	122	27.9	76	24.2
1993	54452.4	49254.1	0.905	92	49	2701	2333	175	47.6	107	40.9
1994	63591.6	58176.1	0.915	110	60	3486	3070	235	51.2	120	42.4
1995	93833.4	88056.0	0.938	127	73	4126	3718	269	50.9	114	40.0
1996	124309.3	114769.8	0.923	143	88	5081	4527	183	51.4	111	43.3
1997	10897.8	10743.6	0.986	86	50	909	778	57	15.6	51	14.8
1998	11698.7	11344.4	0.970	117	83	1345	1150	51	13.9	47	13.5
1999	125621.8	121562.5	0.968	168	105	4695	4449	138	42.4	130	41.3
2000	17100.9	17091.6	0.999	76	63	807	761	42	12.1	41	12.0

A. Total statewide landings (ST)
B. Landings (ST) made by current permitholders
C. Percent of statewide landings made by permitholders (column B/C)
D. Total number of vessels making landings
E. Number of permitted vessels making landings
F. Total number of landings made (includes incidental catch)
G. Number of landings made by permitholders only
H. Maximum landings by a single permitholder
I. Mean number of landings made by a single permitholder
J. Greatest number of days with landings by a single permitholder
K. Mean days with landings by a single permitholder

Table C8. Market squid vessel capacity goal options		
	Number of days fished per season	
Description	130	45
Highly Productive and More Specialized- Assume the maximum catch that would ever be possible for each boat is caught on every trip.	10 vessels operating in this manner could land the maximum seasonal catch.	30 vessels operating in this manner could land the maximum seasonal catch.
Moderately Productive and Specialized - Assume the maximum catch that each boat has ever made is caught on every trip.	19 vessels operating in this manner could land the maximum seasonal catch.	52 vessels operating in this manner could land the maximum seasonal catch.
Less Productive and Less Specialized - Assume the average catch for each boat continues.	31 vessels operating in this manner could land the maximum seasonal catch.	104 vessels operating in this manner could land the maximum seasonal catch.

Market squid vessel capacity goal options

Several capacity goal options for the optimum number of market squid vessels are outlined in Table C8, going from a highly productive and more specialized fleet which fishes squid more often to a less productive and more diversified fleet. Fewer boats will result in the fleet becoming more specialized, and these vessels will presumably need to be more productive for squid, resulting in a fleet with minimal excess or latent capacity. More boats will result in a fleet that is diversified to fish in other fisheries as well as squid, and some vessels of the fleet may fish less often for squid and be less productive. As a result, there may be excess and latent capacity that remains unutilized, and the fleet could be considered overcapitalized. Applying a maximum number of 130 fishing days implies vessels will be focused only on squid fishing activity at the expense of other fishing opportunities such as tuna or other coastal pelagic species, while 45 days of squid fishing reflects an average number of days of participation by the current active fleet prior to implementation of a limited entry program. Likewise, applying the maximum catch a vessel may theoretically ever make serves to generate an estimate of the maximum possible productivity in the fleet, while applying information on an individual vessel's maximum catch may yield a more realistic approach of how the fleet may be expected to perform.

Market squid light boat capacity goal options

Based on a long-term ratio of one light boat per roundhaul vessel during fishing activities, it would follow that the light boat capacity goal option should be consistent with the vessel capacity goal. As light boats do not land the catch, until implementation of the logbook program in 1999 it was virtually impossible to track light boat activity and vessel participation. Consequently, an assessment of light boat fleet capacity cannot be based on vessel-based performance of the fishery at this time, and the vessel capacity goal serves as a suitable proxy.

Market squid brail permit capacity goal options

Optimum brail vessel capacity is difficult to evaluate since it is a small component of the fishery. Based on similar criteria used above for evaluating the vessel capacity goal options, 18 brail vessels operating at their maximum catch levels and an average number of days would catch an amount of squid equal to the highest brail catch on record.